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STATE OF CALIFORNIA

The Resources Agency

Department of Water Resources

BULLETIN No. 74-1

CATHODIC PROTECTION WELL STANDARDS

State of California

Copies of this bulletin at $2.00 each may be ordered from:

State of California
DEPARTMENT OF WATER RESOURCES
P. O. Box 388
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MARCH 1973

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AUTHORIZATION

The program under which this report was prepared is authorized by Section 231 of the Water Code, State of California which reads:

> "231. The department, either independently or in cooperation with any person or any county, state, federal or other agency, shall investigate and survey conditions of damage to quality of underground waters, which conditions are or may be caused by improperly constructed, abandoned or defective wells through the interconnection of strata or the introduction of surface waters into underground waters. The department shall report to the appropriate regional water quality control board its recommendations for minimum standards of well construction in any particular locality in which it deems regulation necessary to protection of quality of underground water, and shall report to the Legislature from time to time, its recommendations for proper sealing of abandoned wells."

In 1967, the Legislature established a procedure for implementing standards developed under Section 231 by enacting Chapter 323, Statutes of 1967, which added Sections 13800 through 13806 to the Water Code. Cathodic protection wells were added to these provisions in 1968. In Section 13800, the Department of Water Resources' reporting responsibility is enlarged upon:

> "13800. The department, after such studies and investigations pursuant to Section 231 as it finds necessary, on determining that water well and cathodic protection well construction, maintenance, abandonment, and destruction standards are needed in an area to protect the quality of water used or which may be used for any beneficial use, shall so report to the appropriate regional water quality control board and to the State Department of Public Health. The report shall contain such recommended standards for water well and cathodic protection well construction, maintenance, abandonment, and destruction as, in the department's opinion, are necessary to protect the quality of any affected water."

FOREWORD

This is a companion publication to Bulletin No. 74 "Water Well Standards: State of California", published in 1968. The standards presented in this report are issued as guides to the construction and destruction of cathodic protection wells in California. Their purpose is to provide additional protection for the quality of our ground water resources.

The Department recommends that all counties and cities consider enacting well construction ordinances that include both water wells and cathodic protection wells. Such ordinances will comprise another step in the continuing effort to protect the usability of California's ground water supplies.

We recognize that effective and useful standards must be periodically revised and updated to reflect both the degree of success achieved in their application and changes in practice. Accordingly the Department will revise these standards as needed.

William R. Gianelli

W. R. Gianelli, Director
Department of Water Resources
The Resources Agency
State of California
February 21, 1973

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This report was prepared by

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ABSTRACT

Water wells have been recognized as a means whereby the quality of ground water can be polluted or otherwise impaired. Cathodic protection wells (or "deep anodes") present similar hazards to ground water quality.

This problem can be alleviated by the proper design and construction of new wells and the proper destruction of wells no longer in use. Standards for the construction and destruction of cathodic protection wells are presented and discussed.

CHAPTER I. INTRODUCTION

Wells are commonly excavated to extract ground water or inject water into the ground. There are other types of wells, however, less common than the water well, constructed for other purposes which penetrate and pass through the underlying aquifers. One of these is the cathodic protection well, or "deep anode" as it is called in the corrosion industry. Cathodic protection wells house devices used to alleviate electrolytic corrosion of pipelines, tanks, and similar installations.

Water wells have been recognized as a means whereby the quality of underground waters can be polluted or otherwise impaired. Such impairment is usually the result of inadequate design or construction or of improper destruction when the well is no longer in use. Actually the construction of any type well, regardless of its purpose, tends to disrupt the geologic environment.

As the number of wells in an area increases, the potential for impairing ground water quality increases. The solution to this problem is to see that wells are designed, constructed, and properly destroyed so that they will not cause deterioration of ground water quality.

If our ground water resources are to be effectively used, we must protect their quality. Recognizing this, the California Legislature enacted legislation directing the Department of Water Resources to develop recommendations for standards for the construction and destruction of water wells (Section 231 of the California Water Code). Later a procedure was established for implementing such standards (Chapter 10 of Division 7 of the Water Code). In 1968, having concluded that cathodic protection wells could also function as instruments for the deterioration of ground water quality, the Legislature amended the Water Code to include such wells.

Bulletin No. 74-1 was prepared in partial fulfillment of the Department's responsibilities under the Water Code and is an extension of the Department's Bulletin No. 74 "Water Well Standards: State of California", February 1968.

A detailed discussion of how wells may contribute to ground water pollution is presented in Bulletin No. 74. Therefore, only the highlights, and particularly those pertaining to cathodic protection wells, are discussed in this bulletin. First, however, because many persons know little about the cathodic protection well, some explanation of its purpose and construction is presented.

Cathodic Protection Wells

Cathodic protection wells are installed to provide protection from corrosion, primarily where extensive conveyance and storage facilities such as oil, natural gas, water and other pipelines, powerlines, telephone cables, tanks, switchyards,

control centers, etc. have been constructed. They are also used to control corrosion in water wells, because the cost of constructing a large capacity water well is increasing, and extending its life is an important consideration.

Corrosion, as used in this bulletin, is defined as the deterioration of metal by electrochemical reaction with the environment in which the metal is situated.* The process is illustrated in Figure 1, which depicts the deterioration of a steel pipeline. The pipeline is situated in a soil-water environment in which the water acts as an electrolyte. As dissolved salts in the water increase, the resistance to the flow of electric current decreases (thus, saline water is an excellent electrolyte). This, coupled with a varying electric potential on the surface of the pipe, establishes a flow of current from a cathode to an anode and causes the removal of metal from the anode. The process gradually weakens the pipe, resulting in its eventual failure.

Cathodic protection is undertaken to prevent or minimize corrosive action by redirecting the current to a substitute anode which then deteriorates instead of the pipeline.

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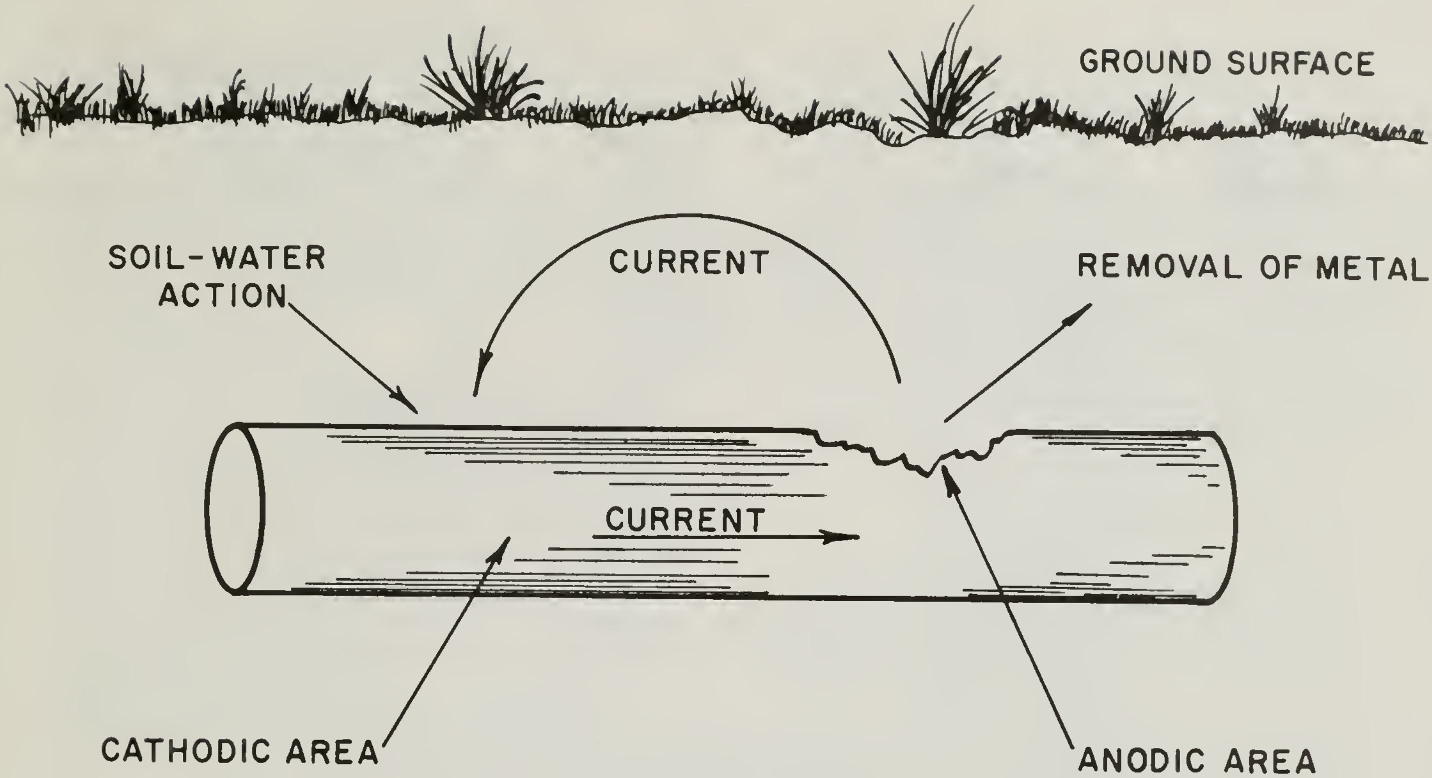
*Note that chemical corrosion, which occurs when a specific compound or element is present in sufficient concentration to bring about removal of a material, is not considered here. Examples would be oxygen, carbon dioxide or hydrochloric acid in a liquid solution flowing through a pipeline.

For a number of years, protective anodes composed of materials that deteriorate slowly have been installed at or close to the surface of the ground. Horizontal or shallow vertical anodes have certain disadvantages, however, particularly in metropolitan areas or in areas of heavily concentrated facilities, e.g., oil fields. In such locations, electrical interference may be high. Moreover, the installation of a large number of horizontal or shallow vertical anodes requires extensive right of way.

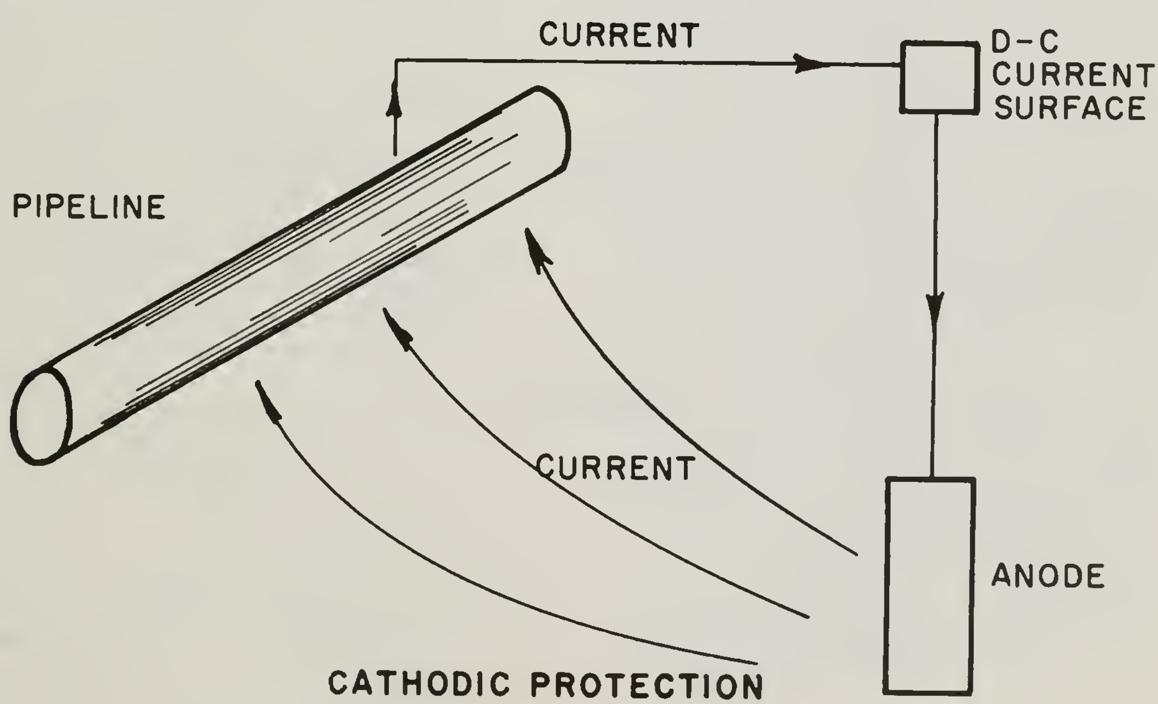
To offset these disadvantages, the vertical deep anode (cathodic protection well) was developed and first used in the 1940's.

A typical deep anode, shown in Figure 2, is constructed by:

1. drilling a hole 6 to 12 inches in diameter to the desired depth;
2. placing a string of anodes in the hole to designated depths;
3. backfilling the anode interval with a conductive material (usually granular carbonaceous material);
4. installing a small-diameter (about one-inch) plastic pipe to vent the gases generated by the decomposition of the anode;
5. backfilling the upper, or "vent", interval with a non-conductive material (usually, a uniform, small-diameter gravel), which provides a further permeable medium for migration of gases, and prevents caving of the walls of the hole;
6. installing a permanent cover over the well;
7. electrically connecting



CORROSION OF PIPELINE



CATHODIC PROTECTION

FIGURE I. GENERALIZED CORROSION SITUATION AND CATHODIC PROTECTION

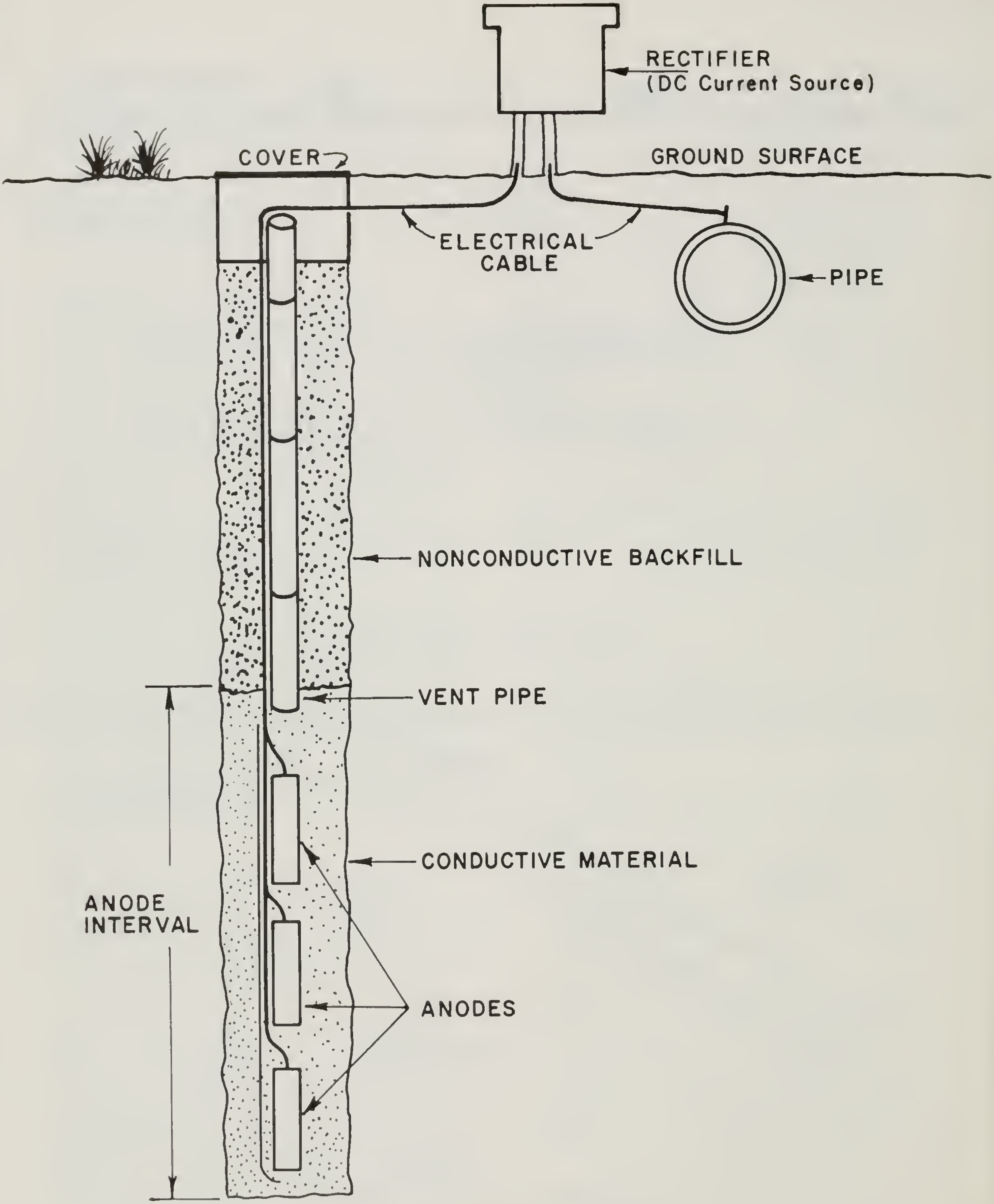


FIGURE 2. TYPICAL CATHODIC PROTECTION WELL (DEEP ANODE)

the anode leads, and leads from the installation to be protected, to a source of current.

Depths of these "deep anodes" normally range from 100 to 500 feet. Installations less than 50-feet deep are considered shallow anodes.

The basic design may, of course, vary. For example, during construction, casing may be used in the uppermost section to hold back caving or sloughing materials such as dune sand. However, casing, which is used in the water well to keep out subsurface materials and to house the pump mechanism, is not normally used in a cathodic protection well.

Now widely used, cathodic protection wells have distinct advantages over horizontal or shallow anodes. These are:

1. Right-of-way costs, particularly in congested areas, are substantially reduced.
2. Less incidence of cathodic protection current interference with nearby unprotected structures. (This has even more future significance considering the advent of direct current electric rail systems and d.c. high voltage transmission systems with their inevitable stray current problems.)
3. Current is made available to a much larger area of the protected structure.

In California, most cathodic protection wells are located in areas where underground conveyance systems are most numerous, i.e., (1) the South Coastal Area from San Diego to Santa Barbara, (2) the San Francisco Bay Area, and (3) the oil-producing areas of the Southern San Joaquin Valley and Central Coast.

Only a few cathodic protection wells have been installed in the rest of California. For example, in the entire State north of Sacramento only an estimated 25-50 wells are known to be in operation.

The Problem

Any improperly constructed (or destroyed) well can endanger ground water quality in three ways. These are:

1. When the surface portion of the well is constructed without protective features, so that water may flow into the well and subsequently into the adjacent formation (Figure 3).
2. When the annular space, that is, the space between the outside of the casing (or, in the case of the cathodic protection well, the vent pipe) and the wall of the hole lacks an adequate vertical seal, and surface or shallow subsurface water may flow laterally into the well and to the adjacent formation along the outside of the casing (Figure 3).
3. When, during well construction (or destruction), aquifers that produce water of undesirable quality are ineffectively sealed off so that interchange of water results in a significant deterioration of the quality of water in one or more other aquifers. In this case the well provides a physical connection between aquifers (Figure 4).

A well that is intentionally or

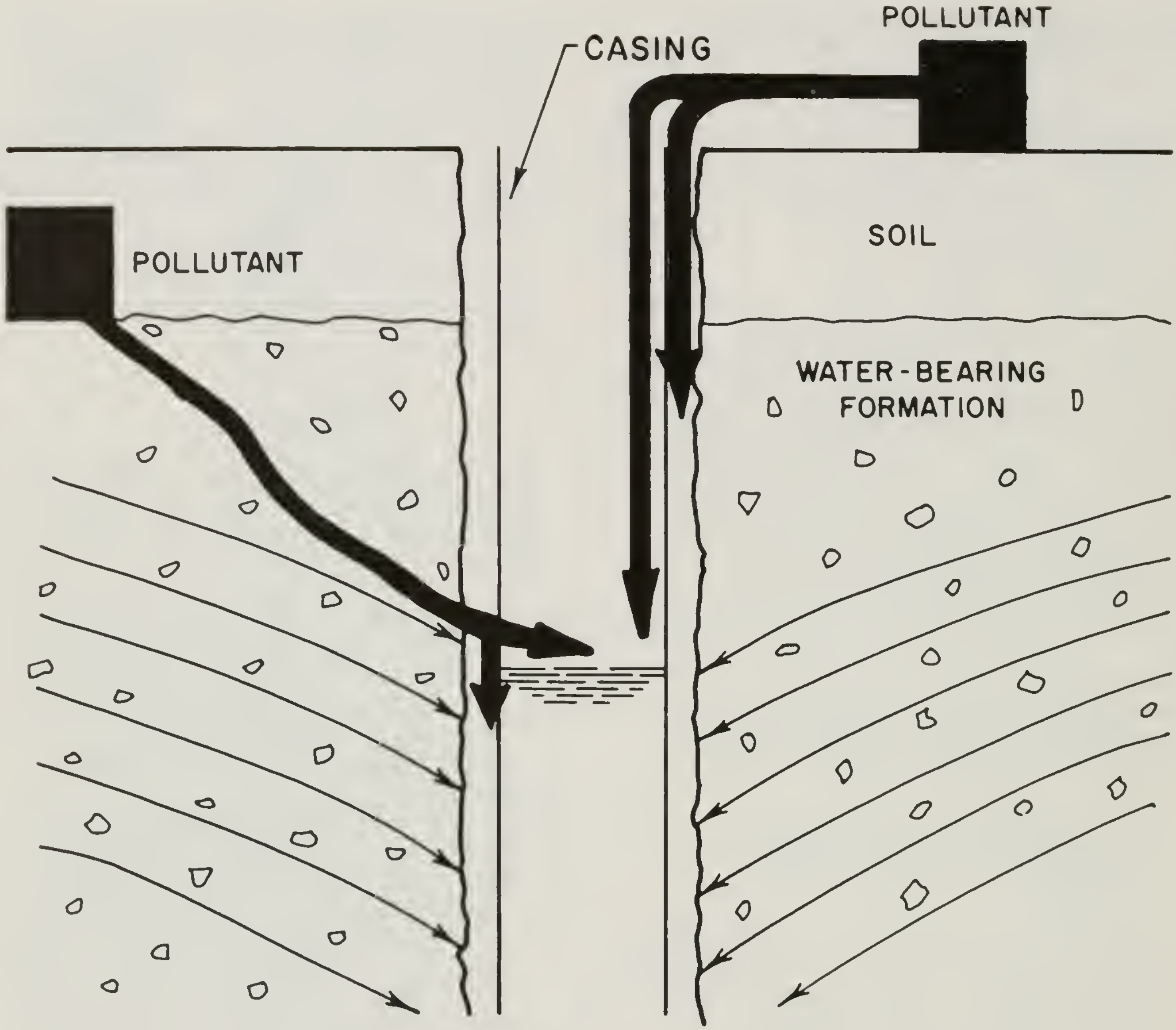


FIGURE 3. SURFACE AND SHALLOW SUBSURFACE POLLUTION OF A WELL AND ADJACENT STRATUM

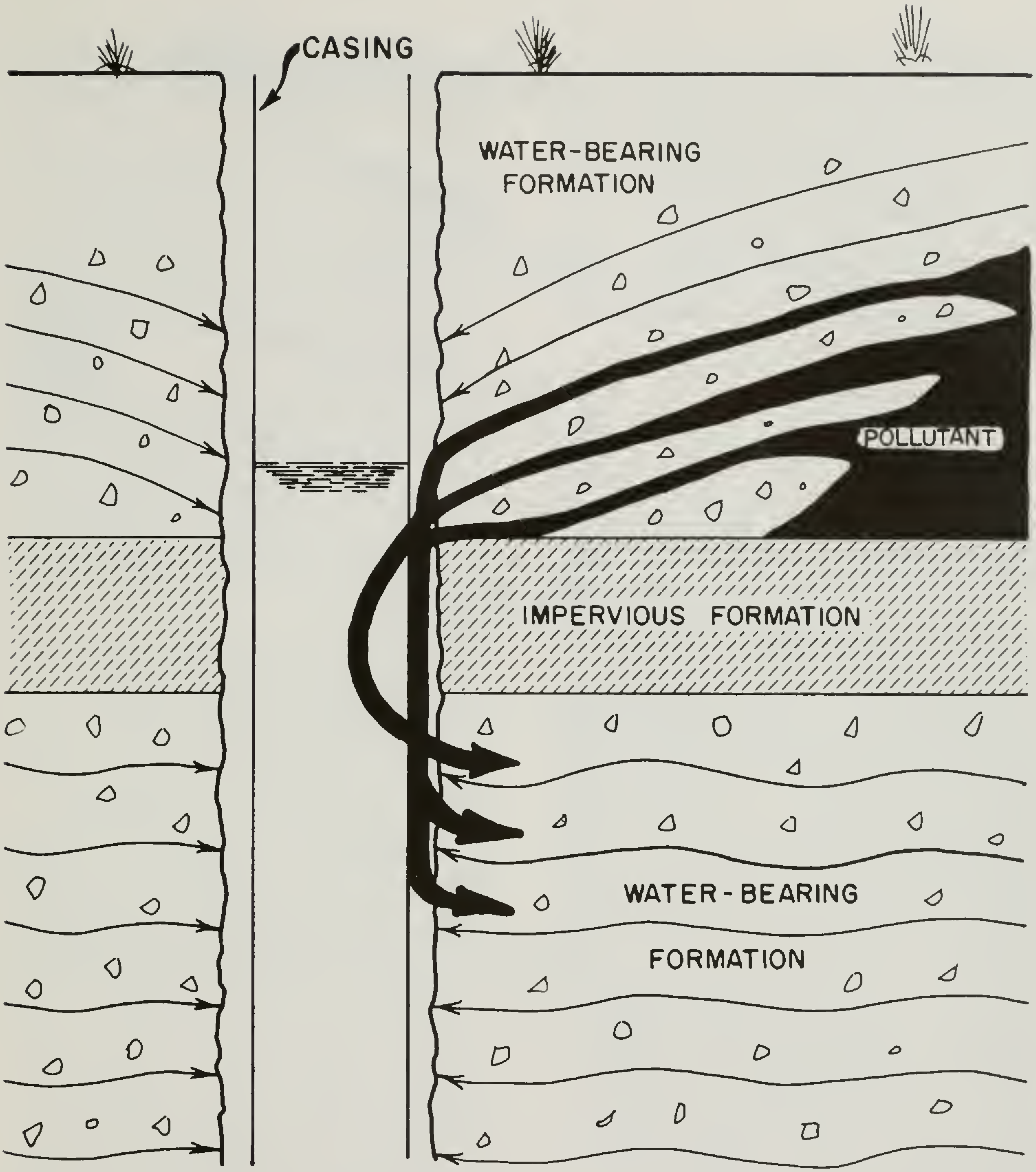


FIGURE 4. MOVEMENT OF POLLUTANT BETWEEN FORMATIONS VIA A WELL

inadvertently used for the disposal of wastes can also be a source of impairment to water quality. However, cathodic protection wells are seldom so used, simply because they have a small opening at the surface. On the other hand, water is sometimes introduced into cathodic protection wells in locations where natural electrolytes are lacking, to keep the system functional. Should the water so introduced be of questionable quality, this practice could be considered as waste disposal. Fortunately, the volumes of water involved are probably small, and the water does not usually migrate appreciably.

Cathodic protection wells constructed as described on Page 10 are particularly conducive to the lateral and vertical movement of fluids. The granular backfilled excavation is uniformly permeable and thus will readily convey pollutants. Consequently, the three conditions that contribute to water quality impairment just outlined can become a reality. This is depicted in Figure 5.

Because of increasing concern for the safety of pipelines that transport natural gas and other hazardous materials, more and more cathodic protection wells are being constructed. The Natural Gas Pipeline Safety Act (Public Law 90-481) adopted by the Congress in August 1968 directs the United States Department of Transportation to establish safety regulations governing the transportation of natural and other gases by pipeline. These regulations (8)* specify that all buried or submerged pipelines be cathodically protected as shown in Table 1.

*See Appendix B, Item 8 for complete title.

These requirements have also been adopted and reiterated by the California Public Utilities Commission (1). Therefore, within the next few years, considerably more cathodic protection wells will probably be installed in California.

Of immediate concern are cathodic protection wells no longer in use. The present practice is to remove the electrical connections and abandon the well. Such a well is a potential intermediary for the travel of pollutants underground and should be destroyed.

The life of the anode in a cathodic protection well will determine the useful life of the well. Anodes are usually designed to last about 15 to 20 years. Fortunately, only a few older wells exist at present, but eventually many wells will be abandoned. However, in recent years there has been a tendency to design and construct wells so that the anodes can be replaced, thus obviating the need to drill a new hole and extending the life of the well several times.

Cathodic protection wells are almost always backfilled and therefore are not a hazard to children and animals, as are abandoned water wells. However, variations in design and increasing vent pipe (or casing) sizes could pose a safety problem as, for example, should the diameter exceed eight inches.

In summary, as stated in Bulletin No. 74:

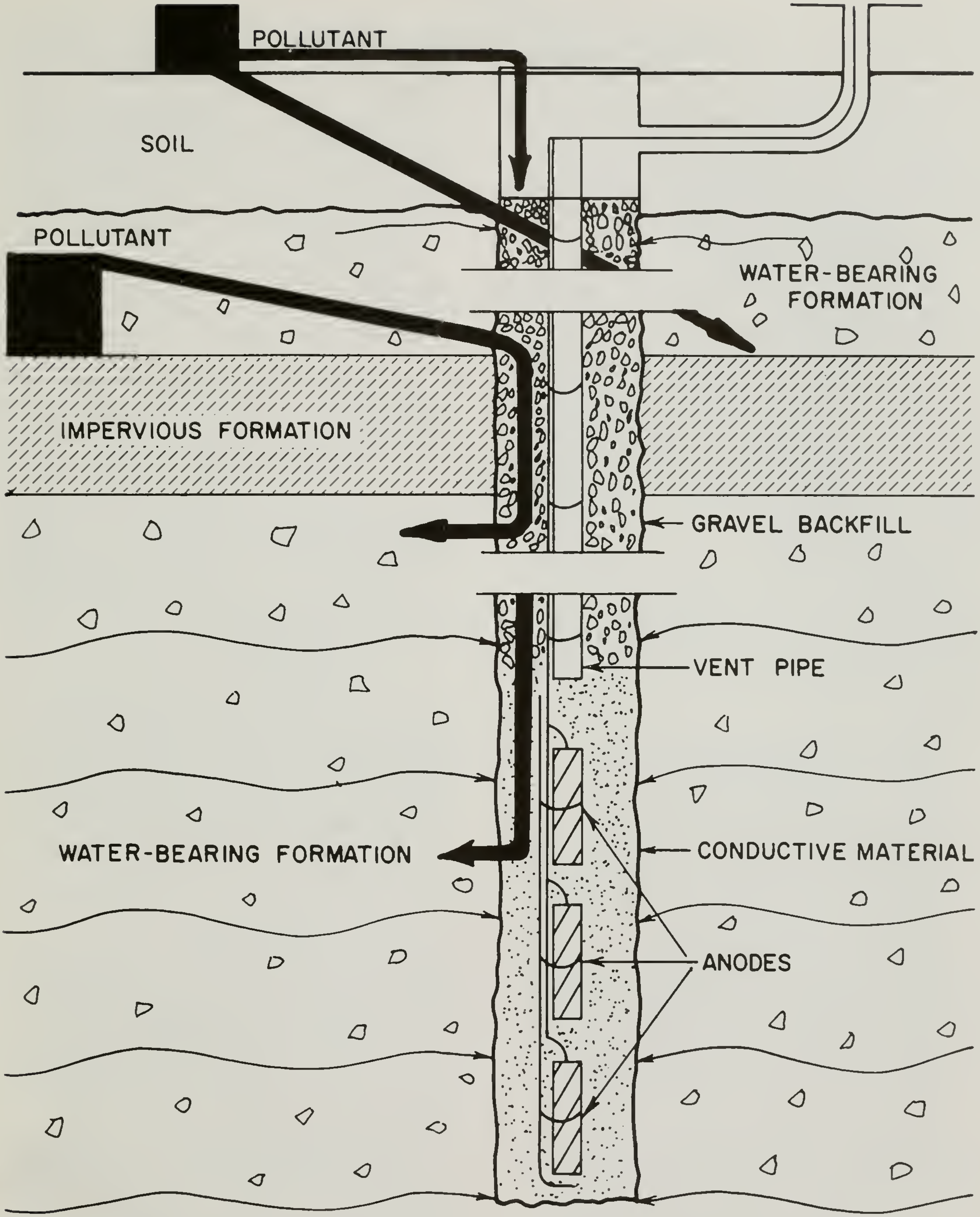


FIGURE 5. TYPICAL DEEP ANODE WELL AND POLLUTANTS

TABLE 1

CATHODIC PROTECTION REQUIREMENTS
FOR PIPELINE SAFETY*

Condition of Pipeline or Location	Date Pipeline Installed	Date Protection Required
1. Transmission Lines with effective external coating.	Prior to 8/1/71	8/1/74
2. In areas where active corrosion is found:	Prior to 8/1/71	8/1/76
a. Bare or ineffectively coated transmission lines.		
b. Bare or coated pipes at compressor, regulator or measuring stations.		
c. Bare or coated distribution lines.		
3. New	After 7/31/71	Within one year after completion

*Adapted from regulations of U. S. Department of Transportation. (8)

"Irrespective of the probability of occurrence and which form of deterioration takes place, California's ground water supplies must be preserved and protected to meet the increasing demands which are being made on them. Moreover, while the well construction industry, advisory groups, and regulatory agencies obviously intend to prevent any impairment of the quality of the State's ground water supplies which might result from improperly constructed or 'abandoned' wells, there appears to be no broad, uniform approach to the development of the means of such prevention in California. It follows then that the resolution of this dilemma requires the development of standards for ... well construction and destruction, which will, if followed, assure the protection of the quality of the State's ground waters ..."

Corrosion Coordinating Committees

Because the various networks of deep anode installations, like the systems they protect, crisscross one another, serious electrical interference problems can develop. For example, the current produced at one anode may affect an adjacent anode or facility. Moreover, in congested areas many "stray" currents are produced. In one instance, the use of salt as a deicer on

electric street railways in the northeastern United States contributed to a lowered resistance between the track and ground, thus increasing the magnitude of currents flowing in the soil. The problem was partially solved by the advent of the trolley bus and liquid fuel driven bus (3). However, with the trend toward direct current electric rail systems and high-voltage transmission lines, this aspect of the stray current problem is renewed.

To overcome these and other problems, corrosion coordinating committees have been formed in many areas. Most are affiliated with the National Association of Corrosion Engineers, and at present there are 33 such affiliates in the United States. Four are located in California. They are:

1. The Joint Committee for the Protection of Underground Structures in Alameda and Contra Costa Counties.
2. Southern California Cathodic Protection Committee (covering all of Southern California south of San Luis Obispo, Kern and Inyo Counties except San Diego County).
3. The San Francisco Committee on Corrosion (including a small portion of San Mateo County).
4. Central California Cathodic Protection Committee (covering all of Central California, the Sacramento Valley Counties and the western Sierra Nevada mountain counties south of Plumas County).

A fifth but informal group, the San Diego County Underground Corrosion Control Committee, deals with that area. There are no groups functioning in the coastal counties north of San Francisco or in the northeastern portion of the State.

These committees represent the majority of the utilities and other companies who install deep anodes. The members keep one another apprised of their organization's plans and coordinate the installation and operation of cathodic protection facilities, thereby minimizing problems of interference from stray currents. Unfortunately, not all those who install and operate cathodic protection facilities are allied with a corrosion coordinating committee. Those not associated with a committee are largely individuals or local agencies (such as school districts) who are usually unaware of the existence of other installations. Often such a facility will produce currents that interfere with nearby deep anode installations. In such cases this may reduce or actually nullify the effect of other cathodic protection installations.

Scope of Program and Report

The purposes of the Department of Water Resources' Well Standards Program are to (1) formulate recommendations for standards to protect the quality of the State's ground water resources from impairment that might result from inadequately constructed, defective, or improperly abandoned wells; and (2) encourage the establishment of these standards throughout the State.

The general statewide water well standards developed are intended for use throughout the State and under the majority of conditions encountered. However, in a number of areas specific information, principally the

definition, both vertically and areally, of affected or endangered aquifers, is needed so that the standards can be applied. For this reason, special studies have been made, and others will be conducted in the future, to develop this information for certain areas of the State. Publications reporting the results of these studies, together with recommendations for the application of standards, have been issued for 10 areas in California. These publications are listed in Table 2.

This report presents recommended standards for the construction and destruction of cathodic protection wells (Chapter II) together with a discussion of their application (Chapter III). The standards contained in this report are intended to be used throughout California. The information presented in the reports listed in Table 2 can be used as an aid in applying these standards in the 10 areas studied.

Technical terms concerning ground water and wells are frequently misunderstood. In an effort to clarify such terms, a list of definitions is presented in Appendix A.

Publications reviewed in preparation of this report are listed in Appendix B. References to publications concerning the development and protection of ground waters and water well construction are contained in Bulletin No. 74.

In accordance with Section 13800 of the Water Code, the Department of Water Resources has recommended to the appropriate California Regional Water Quality Control Boards and the State Department of Public Health that water well standards be established and enforced in the 10 areas listed in Table 2. Ordinances governing well construction and destruction are in effect in five of these areas and are being developed in the other five. In addition several counties have taken the initative and adopted similar ordinances. It is anticipated that all California counties and cities will eventually enact such ordinances.

TABLE 2

REPORTS ISSUED UNDER
WATER WELL STANDARDS PROGRAM
COVERING SPECIFIC AREAS

Area of Study	DWR Bull. No.	Publication Date	CRWQCB No.*	Date Recommended to CRWQCB**
Mendocino County	62	November 1958	1	8/7/69***
West Coast Basin (Los Angeles County)	107	August 1962	4	8/16/68***
Alameda County	74-2	June 1964	2	10/20/69***
Del Norte County	74-3	August 1966	1	6/9/69
Central, Hollywood, and Santa Monica Basins (Los Angeles County)	74-4	Preliminary Edition October 1965 Final Supplement August 1968	4	9/16/68
San Joaquin County	74-5	Preliminary Edition May 1965 Final Supplement July 1969	5	8/12/69
Fresno County	74-6	September 1968	5	1/8/69
Arroyo Grande Basin (San Luis Obispo Co.)	74-7	July 1971	3	5/26/72
Shasta County	74-8	August 1968	5	10/22/68
Ventura County	74-9	August 1968	4 3 5	11/20/68 12/2/68 12/2/68

*1. California Regional Water Quality Control Board, North Coastal Region
2. California Regional Water Quality Control Board, San Francisco Bay Reg.
3. California Regional Water Quality Control Board, Central Coast Region
4. California Regional Water Quality Control Board, Los Angeles Region
5. California Regional Water Quality Control Board, Central Valley Region

**Standards from Bulletin No. 74, "Water Well Standards: State of California", the basic publication in this series also recommended for all areas.

***Memoranda contain updated information and recommendations.

CHAPTER II. STANDARDS

The standards presented in this report for the construction and destruction of cathodic protection wells are considered satisfactory under most conditions throughout the State. However, geologic and ground water conditions vary widely, and to devise standards for every conceivable situation would have been impossible. Accordingly, provision has been made for deviation from the standards and in their application with the objective of providing ground water quality protection equal to that provided by these standards.

The standards recommended are similar to those for water wells set forth in Bulletin No. 74. Because certain general water well standards apply equally to cathodic protection wells, they have been repeated verbatim. The wording in others has been slightly modified. The arrangement is parallel to those for water wells.

Part I. General

Section 1. Definitions

A. Cathodic Protection Well. As defined in Section 13711 of the Water Code:

> "...means any artificial excavation in excess of 50 feet constructed by any method for the purpose of installing equipment or facilities for the protection electrically of metallic equipment in contact with the ground, commonly referred to as cathodic protection."

B. Enforcing Agency. An agency designated by duly authorized local, regional, or state government to administer laws or ordinances pertaining to well construction.

Section 2. Exemption Due to Unusual Conditions.

If the enforcing agency finds that compliance with any of the requirements prescribed herein is impractical for a particular location because of unusual conditions, it may prescribe alternative requirements which are "equal to" these standards in terms of protection obtained.

Section 3. Exclusions.

The standards prescribed in Part II, "Construction", do not apply to test holes or exploratory holes. However, Part III, "Well Destruction", does apply to test holes and exploratory holes.

Section 4. Special Standards.

In locations where existing geologic or ground water conditions require additional or more restrictive standards than those described herein, such special standards may be prescribed by the enforcing agency.

Section 5. Contractors.

Cathodic protection wells shall be constructed by contractors licensed in accordance with the provisions of the Contractors License Law (Division 3,

Chapter 9, of the Business and Professions Code unless exempted by that act.

Section 6. Reports.

Reports concerning the construction of cathodic protection wells shall be filed in accordance with the provisions of Sections 13750 through 13755 (Division 7, Chapter 10, Article 2) of the Water Code.

Section 7. Temporary Cover.

During periods when no work is being done on the well, such as overnight or while waiting for sealing material to set, the well and surrounding excavation, if any, shall be covered. The cover shall be sufficiently strong and well enough anchored to prevent the introduction of foreign material into the well and to protect the public from a potentially hazardous situation.

PART II. Well Construction

Section 8. Well Location with Respect to Pollutants.

A. In congested urban areas or where the cathodic protection well is located within 100 feet of a source of pollution (sewer, septic tank, etc.) the annular space shall be sealed to a depth of at least 50 feet below the land surface (as described in Section 10, following).

B. Where in the opinion of the enforcing agency adverse conditions exist, wells located further than 100 feet from sources of pollution shall be sealed as prescribed in Paragraph A, above, or the depth of seal increased.

Section 9. Surface Construction Features.

A. The top of the well shall be protected against the entrance of surface water draining from the surrounding land by installation of watertight caps, covers, plugs or similar devices.

In drainage ways, exclusive of highways, streets, paved surfaces (such as parking lots, equipment yards, etc.), sidewalks, and the like, the top of the well shall terminate above, or be otherwise protected against, known conditions of flooding.

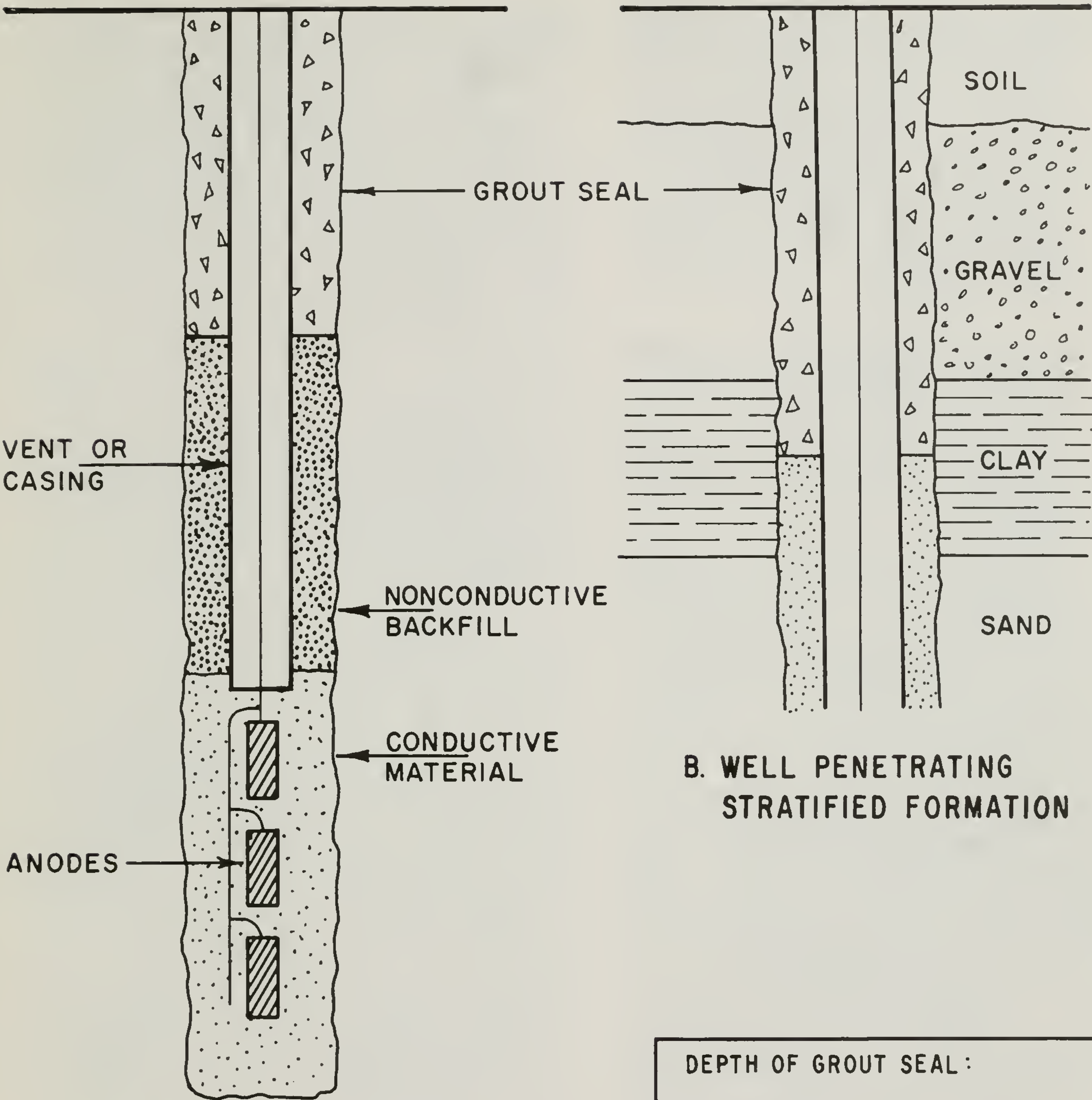
B. When extended above ground surface, the vent pipe shall be terminated at the rectifier housing or other protective housing at an elevation which is above known conditions of flooding.

Section 10. Sealing the Upper or Near-Surface Annular Space.

The space between the well casing or vent pipe and the wall of the drilled hole (the annular space) shall be effectively sealed to protect against contamination or pollution by surface and/or shallow, subsurface waters, as set forth below.

A. Sealing Conditions. Following are requirements to be observed in sealing the annular space:

1. The space shall be filled with sealing material (Paragraph B below) to a depth of at least 20 feet, or as prescribed in Section 8 of these standards, or to the minimum depth (greater than 20 feet) as prescribed by the enforcing agency (Figure 6).



A. GENERAL REQUIREMENT

DEPTH OF GROUT SEAL:

1. NON URBAN AREAS - 20 FEET
2. CONGESTED URBAN AREAS - 50 FEET
3. AS OTHERWISE REQUIRED BY ENFORCING AGENCY (MINIMUM OF 20 FEET)

FIGURE 6. SEALING CONDITIONS FOR UPPER ANNULAR SPACE

2. In wells that penetrate stratified formations, if any impervious formation is encountered within five feet of where the bottom of the seal described in Paragraph 1 of this section would terminate, the seal should be extended into the impervious formation a distance of 10 feet or its total thickness, whichever is least (Figure 6).

3. When a temporary conductor casing is used to hold out caving material during construction of the well or during placement of the seal, it may be left in place or withdrawn as the sealing material is placed.

4. The space between the base of the seal and the anode interval may be filled with granular permeable backfill (such as pea gravel or other inorganic material).* (See Figure 6.)

B. Sealing Material. The sealing material shall consist of neat cement, cement grout, bentonite-gelatinous mud, puddled clay, or concrete. The neat cement mixture shall be composed of one bag (94 pounds) of Type I Portland Cement to five to seven gallons of clean water. Cement grout shall be composed of not more than two parts by weight of sand and one part of cement with five to seven gallons of clean water (per bag of cement). Quick-setting cement, retardants to setting, and other additives, including hydrated lime to make the mix more fluid (up to 10 percent of the volume of cement), and bentonite (up to five percent) to make the mix more fluid and to reduce shrinkage, may be used. Concrete shall be "Class A" (six sacks of Portland Cement per cubic yard) or "Class B" (five sacks per cubic yard).

*It is not intended here to discourage or preclude the practice of sealing the entire upper interval. It may be more practical and economical to do so. However, where the depth of seal is shallow, the owner may wish to exercise the option of backfilling the remainder of the interval.

C. Thickness of Seal. The thickness of the seal shall be at least two (2) inches, and not less than three (3) times the size of the largest coarse aggregate used in the sealing material.

D. Placement of Seal. The sealing material shall be applied, if possible, in one continuous operation from the bottom of the interval to be sealed to the top. Where the seal extends from the anode interval to the ground surface and its depth is extensive, the seal may be applied in steps or a plug may be placed at the top of the anode interval first to provide a base for the seal. If the plug consists of a material that must solidify (cement grout, etc.) it shall extend at least 10 feet and be allowed to set at least 12 hours before placing the remainder of the seal.*

Section 11. Sealing-Off Strata.

In areas where a well penetrates

*The use of quick setting cement is not precluded, in which case the time of set is correspondingly reduced.

more than one aquifer and any of the aquifers contain water of a quality such that, if allowed to mix in sufficient quantity, will result in a significant deterioration* of the quality of water in the other aquifer(s) or the quality of water produced, the strata producing such water shall be sealed-off to prevent entrance of the water into the well or its migration to other aquifer(s).

A. Sealing Conditions. (Figures 7 and 8) The aquifer(s) shall be sealed off by placing impervious material opposite the aquifer and/or opposite confining strata as described in the following paragraphs. Sufficient sealing material shall be applied to fill the annular space between the casing or vent pipe and the wall of the drilled hole in the interval to be sealed, and to fill the voids which might absorb the sealing material.**

Should the top of interval to be sealed lie within 10 feet of where the base of the seal specified in Section 10 of these standards would end, the seal shall extend the full length of the annular space from the ground surface to the bottom of the interval.***

*Significant deterioration is discussed in Chapter III.

Thus the volume of material introduced must at **least equal the calculated volume of annular space to be sealed.

***In many instances sealing the entire interval above the anode interval will expeditiously and economically fulfill the conditions outlined here and in Section 10 of these standards.

Case 1. Upper Aquifers. (Figure 7A) Where the aquifer producing poor quality water lies above the aquifer to be protected, the seal shall extend from the top of the aquifer down to at least 10 feet into the confining stratum (the material separating the two aquifers) or the thickness of the confining stratum whichever is least.

Case 2. Bottom Aquifers. (Figure 7B) Where the aquifer producing poor quality water lies below the aquifer to be protected, the annular space opposite the aquifer itself should not be sealed. Instead the annular space opposite the aquifer to be protected shall be sealed its full length and 10 feet into the confining stratum.

Case 3. Multiple Strata. (Figure 8) Where more than one aquifer produces poor quality water, they are adjacent to one another, and overlie an aquifer to be protected, all overlying aquifers and impervious strata shall be sealed (Figure 8A). Should they underlie the aquifer to be protected, the aquifer and its underlying confining strata for a distance of at least 10 feet shall be sealed off (Figure 8B). If separated by the aquifer to be protected, the upper and lower confining strata, the aquifer to be protected, and the upper aquifer containing poor quality water shall be sealed off (Figure 8C).

B. Sealing material shall consist of neat cement, cement grout, or other suitable impervious material. (See Section 10, Part B).

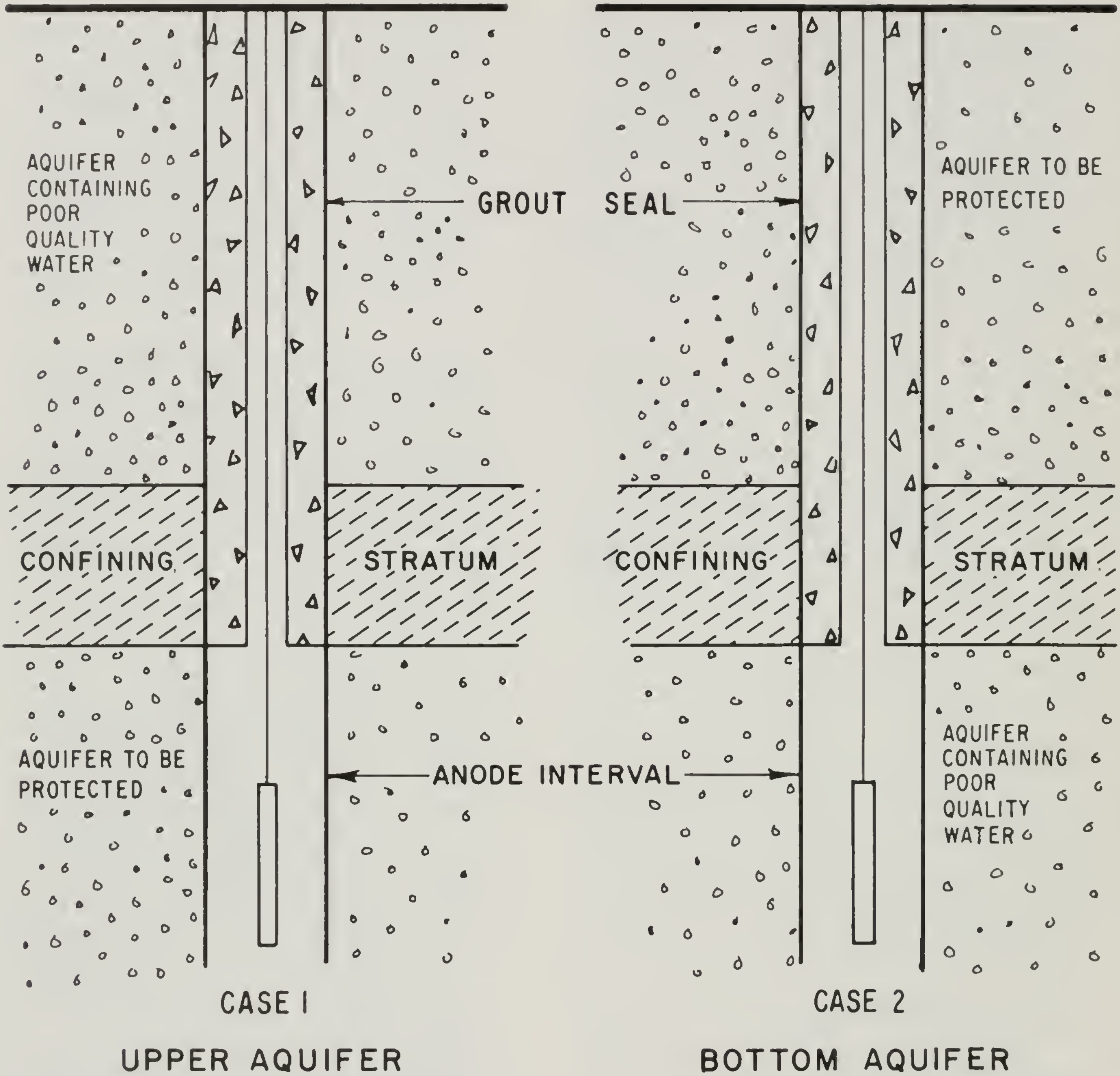


FIGURE 7. SEALING-OFF STRATA

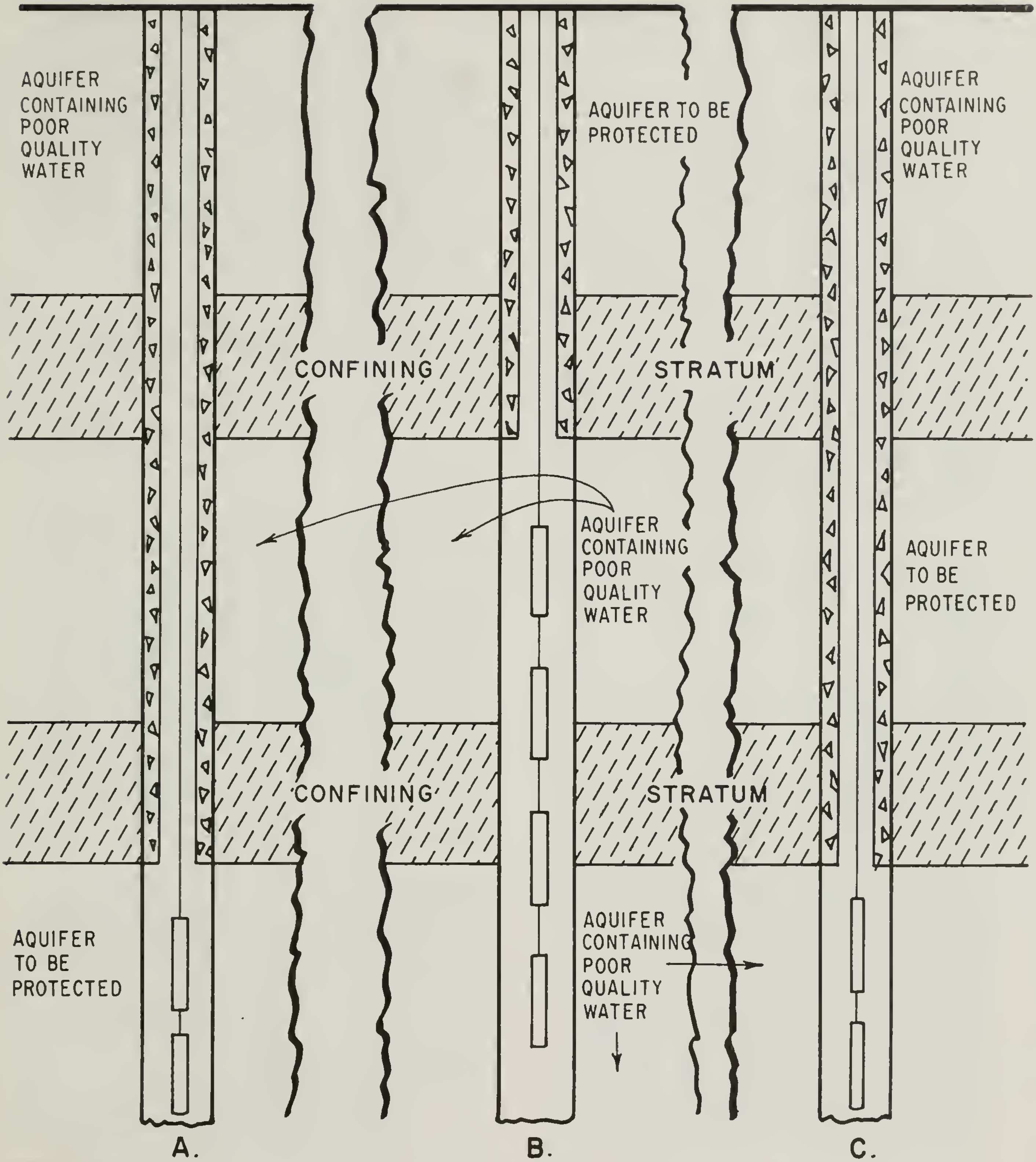


FIGURE 8. SEALING OFF STRATA - CASE 3 - MULTIPLE STRATA

C. Sealing shall be accomplished by a method approved by the enforcing agency.

D. The sealing material shall be placed from the bottom to the top of the interval to be sealed and, if possible, in one continuous operation. If the depth of the sealing interval is extensive and begins at the top of the anode interval, a plug may be placed at the top of the anode interval and the seal may be placed in steps. Should the plug be composed of cement grout or similar material which must "set up" it shall be at least 10 feet thick and shall be allowed to set undisturbed at least 12 hours before placing the remainder of the seal.*

Part III. Destruction of Wells

Section 12. Purpose of Destruction.

Proper destruction of a well that is no longer useful serves two main purposes:

A. To assure that the ground water supply is protected and preserved for further use.

B. To eliminate the potential physical hazard that exists.

Section 13. Definition of "Abandoned" Well.

A cathodic protection well is considered "abandoned" when it has not been used for a period of one year, unless the owner declares his intention to use the well again. As evidence of his intentions for continued use, the owner shall properly maintain the well in such a way that:

A. The well has no defects which will facilitate the impairment of quality of water in the water-bearing formations penetrated.

B. If the casing exceeds eight inches in diameter the well is covered with an appropriate locked cap.

C. The well (or its surface location, if terminated below ground) is marked so that it can be clearly seen.

D. The area surrounding the well is kept clear of brush or debris.

Section 14. General Requirement.

All "abandoned" cathodic protection wells shall be destroyed in such a way that they will not act as a channel for the interchange of waters, when such interchange will result in significant deterioration of the quality of water in any or all water-bearing formations penetrated, or present a hazard to the safety and well-being of people and of animals.

Destruction of a well shall consist of the complete filling of the well in accordance with the procedures described in Section 15 (following).

Section 15. Requirements for Destroying Wells.

A. Objective. The objective of the requirements described in this section is to restore as nearly as possible those subsurface conditions which existed before the well was constructed, taking into account

*The use of quick setting cement is not precluded, in which case the setting time is reduced.

also changes, if any, which have occurred since the time of construction. (For example, an aquifer which may have produced good quality water at one time but which now produces water of interior quality, such as a coastal aquifer that has been invaded by sea water. Under these conditions the aquifer must now be sealed-off to prevent further migration via the well).

B. Preliminary Work. Before the hole is filled, the well shall be investigated to determine if there are conditions which will interfere with the process of filling and sealing. Such conditions will be corrected.

1. If there are any obstructions, they shall be removed, if possible, by cleaning out the hole or by redrilling.

2. Where necessary, to insure that the sealing material fills not only the well casing or vent pipe but also any annular space or nearby voids, the casing or vent pipe should be perforated or otherwise punctured.*

3. In wells that have been constructed prior to the adoption or implementation of the construction standards in Part II, it will be necessary to remove the vent pipe and cables and remove by redrilling* the granular backfill material under conditions described below. Exceptions are those cathodic protection wells constructed since January 1970 in accordance with the design adopted by the Southern California Cathodic Protection Committee (7).

C. Filling and Sealing Conditions. (Figure 9) The following requirements are to be observed when the stated conditions are encountered:

1. Well wholly situated in unconsolidated material in an unconfined ("free") ground water zone. The upper 20 feet shall be sealed with impervious material and the remainder of the well down to the anode interval may be filled with clay, sand, or other suitable inorganic material.

2. Well penetrating several strata. In all cases the upper 20 feet of the well shall be sealed with impervious material.

In areas where the interchange of water between aquifers may result in a significant deterioration of the quality of water in one or more aquifers, or may result in a loss of artesian pressure, the well shall be filled and sealed so as to prevent such interchange. The aquifer producing the deleterious water shall be sealed by placing impervious material opposite the aquifer,

*If wells have been constructed in accordance with the construction standards in Part II, the annular space will have already been sealed and perforating or puncturing the casing or vent pipe will not be necessary.

*An alternate method is the injection under pressure of sealing material into the granular backfill.

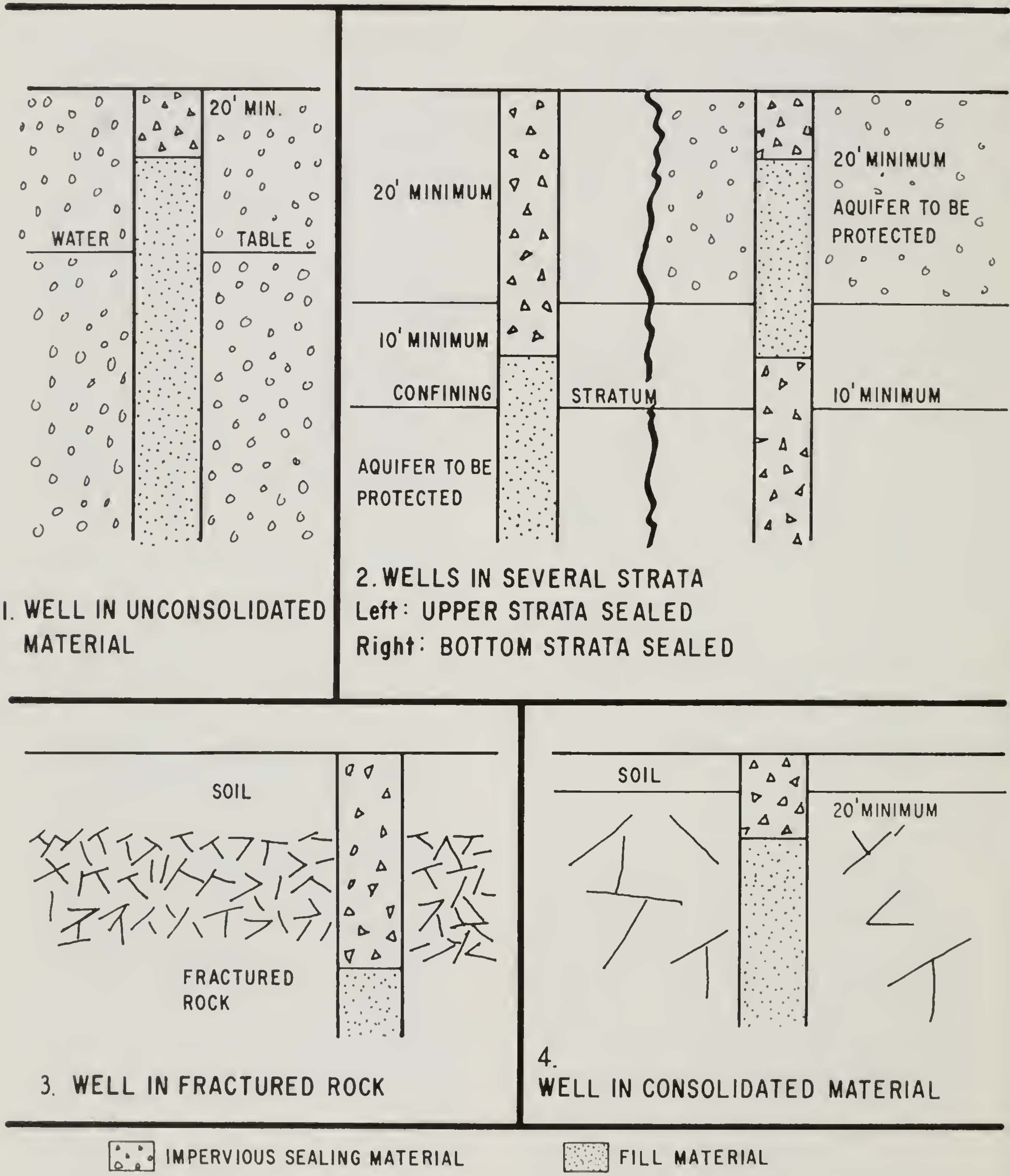


FIGURE 9. WELL DESTRUCTION: SEALING CONDITIONS

and opposite the confining strata for a sufficient vertical distance (but no less than 10 feet) in the direction of confinement. Sand or other suitable inorganic material may be placed opposite the aquifers producing good quality water and other strata where impervious sealing material is not required.*

In locations where interchange is in no way detrimental, suitable inorganic material may be placed opposite the formations penetrated.

3. Wells penetrating creviced or fractured rock. Where creviced or fractured rock is encountered, the portions of the well opposite this material shall be sealed with neat cement, cement grout, or concrete.

4. Well in noncreviced, consolidated material. The upper 20 feet of a well in a noncreviced, consolidated material shall be filled with impervious material. The remainder of the well may be filled with any suitable inorganic material.

5. Well penetrating specific aquifers. Under certain conditions, the enforcing agency may require that specific aquifers be sealed off during destruction of the well.

D. <u>Placement of Material</u>. The following requirements shall be observed in placing fill or sealing material in wells to be destroyed:

1. The well shall be filled with the appropriate material (as described in Paragraph E of this section) from the bottom of the well up.

2. Where neat cement, cement grout, or concrete is used, it shall be placed if possible, in one continuous operation. Where the length of seal is extensive the material may be placed in steps.

3. Sealing material shall be placed in the interval (or intervals) to be sealed by methods that prevent free fall, dilution, and/or separation of aggregates from cementing materials.

4. Where a flow (usually) that is under substantial pressure is encountered, methods must be used to restrict the flow while placing the sealing material. In such cases, the casing must be perforated opposite the area to be sealed and the sealing material forced out under pressure into the surrounding formation.

*Determining the significance of interchange of waters whose qualities vary and of the loss of artesian pressures requires extensive knowledge of the ground water basin in question. The Department of Water Resources has over the years, and frequently in cooperation with agencies such as the U. S. Geological Survey, undertaken a number of ground water studies and amassed considerable information and data about the subject. Although much is known about the State's ground water supplies, detailed studies sufficiently accurate to define interchange problems have been made only in certain areas. In still other areas, there is only partial definition of the problem.

5. When pressure is applied to force sealing material into the annular space, the pressure shall be maintained for a length of time sufficient for the cementing mixture to set.

6. To assure that the well is filled and that there has been no jamming or "bridging" of the material, verification shall be made that the volume of material placed in the well installation at least equals the volume of the empty hole.

To determine that the specified material extends to the required elevation, after each filling operation the depth to the top of the material from the ground surface shall be measured.

E. Materials. Requirements for sealing and fill materials are as follows:

1. Impervious Sealing Materials. No material is completely impervious. However, sealing materials shall have such a low permeability that the volume of water passing through them is of small consequence.

Suitable materials include neat cement, cement grout, concrete, bentonite clays (muds), silt and clays, well-proportioned mixes of silts, sands, and clays (or cement), and native soils* that have a coefficient of permeability of less than 100 feet per year. Used drilling muds are not acceptable.

Neat cement, cement grout, and concrete shall be composed of mixtures described in Section 10, Paragraph B of these standards.

2. Fill Material. Many materials are suitable for use as a filler in destroying wells. These include clay, silt, sand, gravel, crushed stone, native soils,* mixtures of the aforementioned types, and those described in the preceding paragraphs. Material containing organic matter shall not be used.

F. Additional Requirements for Wells in Urban Areas. To make further use of the well site in incorporated areas or unincorporated areas developed for multiple habitation, the following additional requirements must be met:

1. The sealing operation shall extend only to within six feet of the ground surface.

2. After the well has been properly filled, including sufficient time for sealing material to set, the upper six feet of well casing or vent pipe and other surface structures shall be removed and the excavation backfilled with native soil.

*Examples of materials of this type are: Very fine sand with a large percentage of silt or clay, inorganic silts, mixtures of silt and clay, and clay. Native materials should not be used when the sealing operation involves the use of pressure.

*Examples of materials of this type are: Very fine sand with a large percentage of silt or clay, inorganic silts, mixtures of silt and clay, and clay. Native materials should not be used when the sealing operation involves the use of pressure.

CHAPTER III. CONSIDERATIONS IN APPLYING THE STANDARDS

The factors considered in devising standards for wells are grouped into three categories: (1) ground water geology and hydrology, (2) impairment to ground water quality, and (3) well construction practices. The first and second are discussed in detail in Bulletin No. 74, together with a review of water well construction practices. Cathodic protection well construction has been described in Chapter I of this report. How these factors relate to the development of certain of the standards presented in the previous chapter requires explanation. In addition, there are practicalities involved, and such discussion should serve to clarify their application under given circumstances.

First, it is important to recognize that standards, while limiting by nature, are not a limitation on variation in design or means of construction. On the contrary, there can be a great deal of variety in design and method of construction (or destruction) that can satisfy the objectives of standards, and this variety is limited only by the ingenuity of the designer or contractor. Accordingly, there is no intent to limit that ingenuity; rather the intent is to encourage its use.

General Standards

Two of the general standards require further discussion. They are Section 5 "Contractors" and 6 "Reports".

Cathodic protection wells are usually constructed by contractors who specialize in this type of installation. Such contractors are licensed by the State of California under the Contractors' License Law (Division 3, Chapter 9, of the Business and Professions Code). At one time they were classified as C-61 "Limited Specialty" contractors since they worked with low voltages for the most part. Now, however, they usually hold the license classification C-10 "Electrical Contractor" because the installation is primarily an electrical one and involves connection to high voltage lines. The drilling operation is considered essentially one involving the construction of a facility for housing the below-ground protion of the electrical installation. The classification C-57 "Well Drilling Contractor" was established to include all those engaged in the construction, etc. of water wells as defined in Section 7026.3 of the Business and Professions Code.

Therefore, to clarify what might appear to be an ambiguity, it seems clear that a contractor holding a C-10 license can drill the hole for the cathodic protection well (or, as is often the case, sublet the work to a water well drilling contractor). Moreover, whereas a water well drilling contractor could drill the hole he could not assume the prime responsibility for the electrical installation.

For 22 years, persons constructing, altering, or destroying

water wells have been required to file reports of completion with an agency of the state government within 30 days after the work has been completed. These reports must be on forms provided by the Department of Water Resources. They contain much geologic and hydrologic information that is used by governmental agencies in the study of the State's ground water resources and their geologic environment. In 1965 the Legislature directed that a notice of intent to engage in such work also be filed.

In 1968, when legislation adding cathodic protection wells was enacted, the provisions relating to reporting were also amended to include them. However, until these standards were written, it was felt reporting was not completely necessary. (It should be noted here that the corrosion control committees notify members of the installation, activation, and discontinuance of cathodic protection devices; therefore, while details of their construction are not exchanged, the existence of cathodic protection wells constructed by committee members is reasonably documented.) Consequently, the Department of Water Resources did not provide the report forms as prescribed in Sections 13750 and 13751 of the Water Code.

With the publication of these standards and in anticipation of the installation of a larger number of cathodic protection wells, the Department now feels it appropriate to issue the required report forms. Accordingly, following publication of this bulletin, the reports will be developed in cooperation with the corrosion control committees, and printed and distributed to all persons known to install cathodic protection wells in California. Obviously, because deep anode construction is less variable than water well construction, the report requirements will not be as complex or detailed.

Construction Standards

The nature of the cathodic protection installation is such that the practicality of providing cathodic protection may conflict with the application of certain standards when viewed from the resource protection standpoint. Consequently, compromise is in order if both objectives are to be achieved. As a result these particular standards have been modified (in comparison to those for water wells) to accomplish this purpose.

The first of these concerns "Well Location with Respect to Pollutants" (Section 8).* In congested urban areas where underground facilities are a maze of pipelines, cables, tunnels etc., it would be impractical to situate a given deep anode so that it would be at least 50 feet from the nearest sewer line or upgradient from any source of pollution. Therefore, instead of a horizontal distance requirement as specified for water wells, a vertical requirement i.e. the depth of seal, is specified. Accordingly, as described in Sections 8 and 10, in urban areas the minimum depth of seal is set at 50 feet as a substitute for a horizontal requirement.

*For a discussion of pollution as related to location the reader is referred to Bulletin No. 74.

Section 9 "Surface Construction Features" deals with protection of the well against flooding by drainage or runoff from the immediate area because of the danger of introducing pollutants to the underlying water (as described on Page 13). Vaults, meter boxes, "street caps" and the like are commonly installed at the well site and usually of a construction that will prevent the entrance of significant quantities of water into the well. Likewise all cable conduits and many vent pipes terminate in vaults or the rectifier housing usually above flood levels.

It is not intended here to preclude the installation of deep anodes in streets, sidewalks, parking lots, etc. as commonly practiced. However, it is intended that the owner and/or contractor consciously provide for protection against flooding. Further, in circumstances where surface drainage is inadequate or lacking (such as natural low spots, sumps, etc.) protection may include terminating the top of the well above known conditions of flooding.

Some comments regarding the sealing material and its placement under Section 10 "Sealing the Upper or Near-Surface Annular Space" and Section 11 "Sealing-Off Strata" are deemed necessary. While all the materials listed will provide an adequate seal, experience has shown that cement grout (sand, cement and water) and neat cement (cement and water) are the most effective seals. The first is less expensive than the second, both are easy to mix, and handling problems are minimal.

Where seals are extensive, on the order of 100 feet or more in depth, conductive material used in backfilling the anode interval is sometimes unable to support the weight of sealing material. Consequently, provision has been made for the installation of a plug consisting of a short section of sealing material at the top of the anode interval. The plug must be capable of supporting the sealing material until it sets.

Several aspects of the requirements of Section 11 "Sealing-Off Strata" must be considered in connection with its application. Foremost is the significance of interchange of waters of differing qualities, a point frequently misunderstood or misinterpreted. The interchange of waters between aquifers when they are of differing qualities is undesirable (and therefore to be prevented) when the quality of the one is significantly poorer than the other and the quantity involved in such interchange is significant.

To illustrate, a cupful of salt water mixed into a 50 gallon drum of fresh water has little effect on the fresh water. Adding ten cups of salt water is another thing; the effect will be "significant". On the other hand, adding only one cup of arsenic to the drum will obviously have immediate significance!

That a significant change of quality in one aquifer as a result of the introduction of poor quality water from another has taken place is evidenced by the effects on the uses to which the pumped water is put. Changes in quality have been severe enough in certain areas to limit

use of the water and in some instances eventually led to the abandonment of water wells.

In contrast, the mixing of waters of differing qualities can also be of little or no consequence. However, the possibility of significant interchange must be considered if it has not already been established. The Department of Water Resources has made such a determination in areas where well standards studies have been conducted (see Table 2, Chapter 1) and in time will do so in other areas of the State. The Department also has a great deal of information concerning geologic and ground water conditions throughout California which is available to the public. While not every locale is covered, in many areas the data are sufficient to make a gross judgment as to whether or not interchange is likely to be involved. Where no information exists and the problem is suspected, a determination must be made at the well site during construction.

The next consideration is the areal extent of the significant interchange both existing and projected. Frequently, those who misunderstand the interchange problem are inclined to view its areal extent as exaggerated. Two cases must be considered; the upward moving "bottom" waters and those whose movement is primarily (but not always) downward.

Poor quality "bottom" waters i.e. those waters underlying the lowest zones of fresh water supplies, usually at great depth and under pressure, are very extensive. The entire Central Valley of California for example is underlain by poor quality waters with depths ranging from just a few hundred feet in some locations to thousands of feet below the land surface. In the case of water wells, deliberate penetration of bottom waters is to be avoided.* The recommendation for water wells is to cease drilling within a reasonable vertical distance from such waters where the base of fresh water is known or, if bottom waters are penetrated, to backfill the drilled hole with impervious material a sufficient distance to prevent upward movement.

In the case of the water whose movement, unless checked, is downward, their areal extent, even those that have been projected, is much less in magnitude. Of the 10 areas where the Department has conducted studies and issued formal recommendations, prevention of downward interchange was not deemed necessary in one (Del Norte County) and in the others preventive measures are recommended for areas which extend to 2,400 square miles (about 40 percent) out of 5,800 square miles of water bearing materials.

A final consideration dealing with the sealing off of strata is the conflict in purpose which may arise when on the one-hand interchange is to be

*However, it must be recognized that there are circumstances when extraction of saline water is feasible or necessary as for example the use of such water for injection into oil and gas fields to aid in recovery of oil and gas or where desalination is practical.

prevented, while on the other hand such action would hinder or possibly nullify the operation of a deep anode installation. The corrosion engineer, in selecting the depth at which he will place his anodes, is looking for water with low resistance to the flow of electric current. Since the salinity of water is related to resistance (i. e. as the salinity increases the resistance decreases), he is obligated to use the most saline waters penetrated. Thus, the zone to be sealed-off is possibly the very zone needed to provide the desired length of anode interval.

In the case of a bottom water or a water that is below an aquifer to be protected, this presents no problems. The recommendations call for a seal which will prevent upward movement. However, where downward moving waters are involved, the situation can be conflicting.

An extreme hypothetical example might be a location where the downward movement of the upper 400 feet of water must be prevented. Assuming the water to be saline, it is difficult to envision constructing the deep anode beyond the 400 foot depth. At worst the linear extent of the facility being cathodically protected could require installation of additional 400 foot deep anodes. In any event, the exercise of good judgment and ingenuity in design should overcome situations that appear conflicting without an unreasonable increase in cost or, for that matter, any increase in cost.

Destruction Standards

Because destruction seldom is of direct personal benefit to the well owner, he is reluctant to expend the effort and funds involved in doing such work. This is, unfortunately, a selfish point of view, and in the long run, one which could result in problems and economic loss to him as well as his neighbors.

The concept that all have an interest in our water resources, and therefore an obligation to protect them for their present and continued use, is a fundamental one. It holds true whether the issue is construction or destruction, or whether water wells or cathodic protection wells (or other kinds of holes in the ground) are involved.

The general requirement (Section 14) that all cathodic protection wells be destroyed is based on the premise that no opening should be left which would allow movement of water or which would present a safety hazard. Furthermore, the Department has long concluded that complete filling as a method of destruction eliminates all existing or potential problems at the well site. Other methods such as plugging at selected intervals or just at the top are valid only so long as the plug remains intact and in position.

With regard to Section 15 "Requirements for Destroying Wells", three points should be reviewed. The first involves preliminary work on wells constructed previous to the implementation of these standards (Section 15, Paragraph B3). The requirement that the vent pipe and cables be removed and the backfill be "drilled out"

(by redrilling) imposes no difficult undertakings: in fact, redrilling should prove to be easier than the original drilling. While it is possible that, over a considerable period of time, the openings in the backfill could be filled with fine-grained material or "cemented up", it is not considered likely to occur throughout the entire length of the backfill column. Too frequently, a "bridge" in the material is formed and the remainder of the column unchanged. Thus, the only sure way to eliminate the backfill as a channel for water movement is to remove it or to inject a sealing material into it.

It is also possible that some sections of the vent pipe can become wedged or cemented in place and thus not easily pulled. This also happens where water wells are concerned. However, water well drilling contractors have pulled steel casing of diameters in excess of 12 inches that have been surrounded by gravel and other material with considerable success. It would appear that removal of a two-inch plastic pipe and as many as a dozen anode cables from a gravel envelope should be no more difficult.

The second point is the filling and sealing conditions in Section 15, Paragraph C. The requirements are designed to assure complete filling of the well and that sealing takes place at specific intervals. It should be apparent that in many cases it will be more practical or economical to seal the entire well with an impervious material. Furthermore, in the case of wells constructed in accordance with these standards (see Part II), it is reemphasized that sealing of the vent pipe or casing with impervious material is all that will usually be necessary in the future.

Finally, in regard to additional requirements for wells in urban areas (Section 15, Paragraph F), the assumption is made that the site can be used again for another purpose at some unknown future date. In fact, the installation being protected may be removed or relocated. Thus, at the time of destruction, allowance should be made for future use.

APPENDIX A

DEFINITION OF TERMS

The following terms are defined as used in this report:

Abandoned Well - A well whose original purpose and use has been permanently discontinued or which is in such a state of disrepair that its original purpose cannot be reasonably achieved.

Annular Space - The space between two well casings or a well casing and the wall of the drilled hole.

Anode - An electrode at which oxidation is occurring on its surface or on one component of the solution.*

Aquifer - A formation or group of formations or part of a formation that is water bearing, and which transmits water in sufficient quantity to supply pumping wells.

Backfill - Material placed in the drilled hole to fill space around anodes, vent pipe, and other components.*

Casing - A tubular retaining structure which is installed in the excavated hole.

Cathodic Protection - A technique to reduce corrosion of a metal surface by passing sufficient cathodic current to it to cause its anodic dissolution rate to become negligible.*

Clay - A fine-grained inorganic material (grains less than 0.005 mm in diameter) which has very low permeability and is plastic.

Confined Ground Water - A body of ground water overlain by material sufficiently impervious to sever free hydraulic connection with all overlying ground water except at the upper edge of the confining stratum where the confined water connects with free ground water. Confined ground water moves in strata, conduits or arteries under the control of the difference in head between the intake and discharge areas of the confined water body.

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*Definitions from National Association of Corrosion Engineers Standard RP-05-72.

Contamination - Defined in Section 13050 of the California Water Code:

> "(k) 'Contamination' means an impairment of the quality of the waters of the state by waste to a degree which creates a hazard to the public health through poisoning or through the spread of disease. 'Contamination' shall include any equivalent effect resulting from the disposal of waste, whether or not waters of the state are affected."

Corrosion - The deterioration of a material, usually a metal, because of a reaction with its environment.*

Deep Groundbed - One or more anodes installed vertically at a nominal depth of 50 feet or more below the earth's surface in a drilled hole for the purpose of supplying cathodic protection for an underground or submerged metallic structure.*

Deterioration - An impairment of water quality.

Driller's Mud - A fluid composed of water and clay (either native clay or combination with commercial clays) used in the drilling (primarily rotary) operation to remove cuttings from the hole, to clean and cool the bit, to reduce friction between the drill stem and the sides of the hole, and to plaster the sides of the hole. Such fluids range from relatively clear water to carefully prepared mixtures of special purpose compounds.

Electrolysis - The chemical change in an electrolyte resulting from the passage of electricity. Electrolysis is the dissociation of an electrolyte by passage of direct current, in which anions are discharged at the anode and cations at the cathode. Elements released at the anode may include oxygen, chlorine, and other gases. Hydrogen is the element commonly released at the cathode.*

Electrolyte - A chemical substance or mixture, usually liquid, containing ions that migrate in an electric field. The term electrolyte refers to the soil or liquid adjacent to and in contact with a groundbed or metallic structure, including the moisture and other chemicals contained therein.*

Ground Water - That part of the subsurface water which is in the zone of saturation.

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*Definitions from National Association of Corrosion Engineers Standard RP-05-72.

Ground Water Basin - A ground water basin consists of an area underlain by permeable materials which are capable of furnishing a significant water supply; the basin includes both the surface area and the permeable materials beneath it.

Grout - A fluid mixture of cement and water (neat cement) of a consistency that can be forced through a pipe and placed as required. Various additives, such as sand, bentonite, and hydrated lime, are included in the mixture to meet certain requirements. For example, sand is added when a considerable volume of grout is needed.

Interference - The situation that arises when a foreign substructure is affected in any way by a direct current source.

Impairment - A change in quality of water which makes it less suitable for beneficial use.

Impermeable - Having a texture that does not permit water to move through it perceptibly under the head differences ordinarily found in subsurface water.

Impervious Stratum - A formation, group of formations, or part of a formation which, although often capable of absorbing water slowly, will not transmit it fast enough to furnish an appreciable supply for wells or springs.

Impressed Current - Direct current supplied by a device employing a power source external to the anode system.*

Permeability - The capacity of a material for transmitting a fluid. Degree of permeability depends upon the size and shape of the pores, the size and shape of their interconnections, and the extent of the latter.

Pollution - Defined in Section 13050 of the California Water Code:

> "(l) 'Pollution' means an alteration of the quality of the waters of the state by waste to a degree which unreasonably affects: (1) such waters for beneficial uses, or (2) facilities which serve such beneficial uses. 'Pollution' may include 'contamination'."

Pressure Grouting - A method of forcing grout into specific portions of a well, such as the annular space or into the surrounding formation, for sealing purposes.

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*Definition from National Association of Corrosion Engineers Standard RP-05-72.

Puddled Clay - Clay or a mixture of clay and sand, kneaded or worked when wet to render it impervious to water.

Quality of Water or Water Quality - Defined in Section 13050 of the California Water Code:

> "(g) 'Quality of the water' or 'quality of the waters' refers to chemical, physical, biological, bacteriological, radiological, and other properties and characteristics of water which affect its use."

Unconfined Ground Water - Water moving through an interconnected body of pervious material unhampered by impervious confining material, and moving under control of the water table slope.

APPENDIX B

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